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On the organization of the dependability service in a machine-building company

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Abstract. *Historically, dependability services originated within design units of companies. A design engineer had his/her own ideas about the quality control of released products. As the initial application field of the dependability theory was the aerospace industry, he/she understood that the presence of errors and omissions within a product could cause catastrophic consequences [1]. Along with the dependability unit the quality and technical supervision service was developing, and that was primarily tasked with organizing and conducting acceptance testing, receiving inspection and prevention of a product's non-compliance with technical documentation. At one point, a conflict arouse between the two branches, which lead to a general misunderstanding of responsibilities and disorganization of the product dependability control. As a result, in some companies the dependability service is integrated with the quality service, in others it is subordinated to the design bureau. Additionally, operational dependability evaluation requires an uninterruptible source of reliable information on the reliability and maintainability of the equipment. The quality of this information depends on the interaction between the dependability service and the maintenance service. The latter is to compare the repair reports that specify the recovery time and operation time of the product and promptly submit that data for dependability calculation. Thus, the following questions arise: which activities are to be performed by the dependability service, who is to be subordinated to whom, who is the owner of the processes associated with the estimation of dependability parameters? It is important to understand the purpose of establishing a dependability unit in a company, what authority its employees possess, what results the management expects to obtain. The formalization of the research findings presents a problem. As of today, there is no single approach to formalized calculations, preparation of dependability analysis reports. The research findings are to be sent to all the involved business units, therefore a convenient form of information representation must be developed. A special attention must be given to personnel training in terms of technical system dependability. Industrial products become more and more complex, new technologies are developed, and old approaches to dependability calculation and analysis do not always ensure acceptable results. That is not surprising, as the significance of the use of reliable and substantiated methods of dependability estimation is very understated. That is due to the fact, that many believe that the dependability theory is based on the research of the physical, design-specific causes of failure, physicochemical processes, etc., meaning that a dependability engineer is first and foremost a design or process engineer. However, it should not be forgotten that the general dependability theory is subdivided into the mathematical (mathematical methods of the probability theory), statistical (method of mathematical statistics) and physical (research of materials properties variations). Subsequently, a dependability service is to conduct analysis based on competent application of mathematics alongside activities associated with products design research. Proposals regarding future developments in this area, including the education system, will be welcome.* **Aim.** *To propose an approach to the organization of the dependability service in a modern machine-building company taking into account advanced methods and concepts of dependability analysis at all lifecycle stages of a product.* **Conclusions.** *The paper suggests an organizational structure of a dependability unit for a transport machine building company. The interactions between the dependability service and other business units is examined. A number of factors affecting the efficient operation of the dependability service are identified.*

Keyword: *dependability theory, dependability service, engineering, organizational structure, operational efficiency, human resources management.*

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Introduction

As of late, the problem of dependability estimation of output products has been growing in importance. The organization of a company's dependability service is necessary and relevant in such areas as transport machine-building, automobile production, aircraft industry. However, this subject matter is not extensively covered in foreign and Russian literature. For instance, [2] examines the dependability service functionality only in terms of product development. In [3], the matters and approaches to product operation data processing are examined, yet no algorithm for controlling this process algorithm is proposed.

In [4], the following concept of dependability bureau functionality is set forth: "The dependability bureau performs guidance over the key business units and coordinates the measures aimed at improving the dependability of the output products. The functions of the dependability service are an obligatory part of the general technical policy of a company."

In the meantime, as the scope and range of products grow, the requirements for the competence of the employees involved in the calculation and compliance verification of dependability indicators are increasing as well. A dependability team that consists of capable people, but that is part of another unit and does not have sufficient authority, is an unnecessary luxury [5].

A company's management must be interested in correct operation of the dependability service, vest it with required authorities and involve the unit's employees in the solution of relevant issues in the course of design and operation.

A company that has a qualified dependability service can manage its economic efficiency in the following ways:

• reducing the scope of costly tests or even replacing some items of the respective methods with dependability indicator calculation data obtained in operation that are equivalent in terms of efficiency and correctness;

• recording accurate information on failures of automated data collection systems, which subsequently enables speedy repairs (STPA, unfailing source of supply, etc. are predefined depending on the place of operation) and modify a product's design;

• predicting dependability indicators at various lifecycle stages in order to enable production schedule adjustment and selection of optimal service and repair strategy;

• reducing costs associated with disruption of supplies based on the prediction of dependability-oriented demand for various types of components of the output products.

Dependability service functionality

One of the possible problems at the early stages of dependability service operations is the lack of clear responsibility delimitation. That is due to the fact that the matters of dependability pertain to the interests of the maintenance service, design unit, process engineering bureau and unit responsible for testing to name just a few.

It is not uncommon when the difference between the estimation of dependability and quality is misunderstood. They are often considered to be the same thing, as they have common analytical tools. For instance, FMEA (Failure Mode and Effects Analysis) can be performed by both quality and dependability engineers, however the results will differ. The role of the quality service consists in assessing (the process) of product manufacture, component supplier control. A dependability engineer examines the failure mechanisms that affect the product's operability; identifies the failure frequency patterns using statistical methods; analyses dependent failures of the elements that affect other parts of the system. For that reason, while everyone uses the same FMEA tool, it is used for different purposes: a quality engineer assesses an industrial process, while a dependability engineer assesses a product's design.

Maximizing the efficiency of dependability supervision organization requires identifying the primary functions of the dependability service of a machine-building company:

• product dependability calculation;

• development of structure diagrams of dependability;

• development of programs and methods of operational dependability testing;

• introduction of dependability estimation in the development plan of any product;

• substantiation of the limit values of mean time to failure and recovery time;

• analysis of the common database of dependability longevity tests;

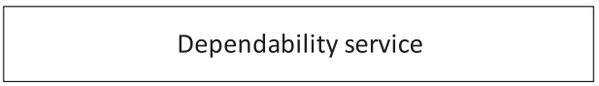
• supervision of completion and optimization of claim register structure;

• informing the company's employees on failures and development of recommendations for various units, whose activities affect the final dependability characteristics of a product.

A certain procedure must be established to regulate the delivery of information materials to the dependability unit. It is recommended to adopt obligatory review by the dependability service employees of such documents as the technical conditions, operator's manuals, program and method of testing, etc. [1].

Organizational structure

If a company views itself as an organization involved in dependability analysis, the responsibility for the design, system engineering, life cycle calculation and responsibility for product quality and dependability assessment should be distinguished. From the project management point of view, it is very important not to miss the stage of development, at which the dependability analysis is conducted. If otherwise, the project itself (prototype manufacture/commencement of batch manufacture, etc.) may become irrelevant, as dependability calculation at the design stage is essentially risk analysis, and incorrectly calculated risks can undermine any project. A common problem is when dependability engineers



Education	Higher	Higher	Higher	Vocational secondary
Working day	Secondary/Full employment	Secondary/Full employment	Full/Contract/Partial	Full employment
Duties	• Calculation of products' dependability indicators in operation • Development of method of estimations of dependability indicators in operation • Development of dependability standards and guidelines • Dependability estimation at the stage of design • Development of recommendations for increased products dependability • Calculation of dependability indicators required for LCC		• Development of programs and applications for automated dependability calculation (according to dependability engineer's specifications) • S&R database administration	• Preparation of documents • Collection of specific information • Logging

Figure 1 – Organizational structure of dependability service.

are tasked with functions they have nothing to do with. An example is life cycle cost (LCC) calculation, of which the process is often assigned to the dependability engineer, while the dependability unit is only responsible for two types of parameter (out of over 10 involved in the calculation), i.e. the failure flow and mean time to restoration of the structure's units and components.

In [6], it is stressed that a company's management is to be responsible for all dependability-related performance indicators; a list of primary requirements for successful organization of dependability management processes is given.

In [7], three models for organization of dependability engineer operations within a company are considered, i.e. functional (linear), project-oriented and matrix models. The linear model implies direct subordination of the dependability engineer to the head of the unit that he/she is assigned to. That may be the quality service or the design bureau. This approach implies the presence of one or two dependability engineers and a dependability coordination manager. An obvious shortcoming of this approach consists in the fact that manufacturing and field data need to be obtained, which requires assistance from other units of the company. In a project-oriented

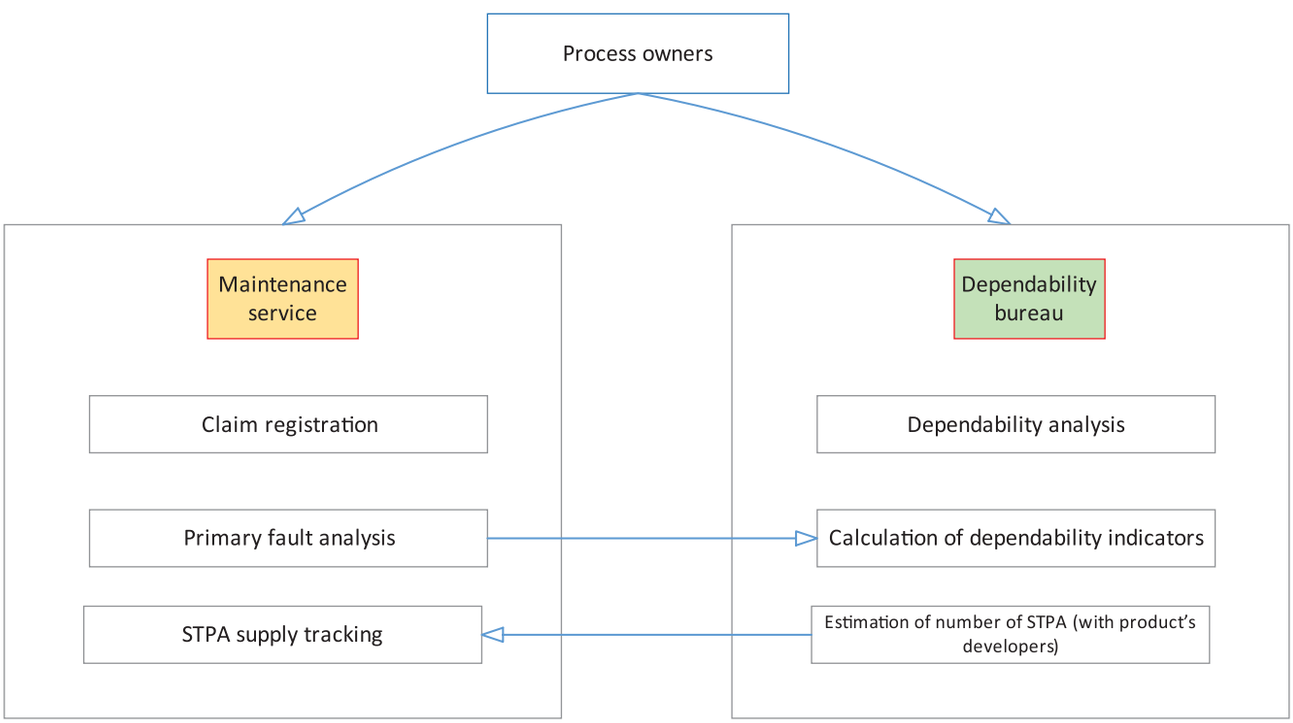


Figure 2 – Interaction between the maintenance service and the dependability service.

structure, the dependability engineer is appointed as part of a specific project and supports a single product. Thus, a dependability service is decentralized, which causes increased support of a product with unique problems that require special attention. On the other hand, decentralization causes duplication of functions and processes per each type of product. A single approach to dependability analysis, e.g. FMEA, may be not in place either. In case of matrix organization the employees of the dependability service belong to a single structure, e.g. the design bureau, but, if required, are temporarily assigned to specific products or projects. Thus, this approach is a combination of the above structures. The matrix organization implies the presence of a coordination manager for dependability and standardization of dependability analysis processes. The structure is flexible, but at the same time subordination-related conflicts may arise. The employees may receive orders from the manager, rather than their direct superior.

An organizational structure of the dependability service is examined in [8]. It implies a three-level system with the lead engineer at the top, design, logistics and system engineering managers at the second level. The bottom level consist of a design engineer with the knowledge of design dependability, a service engineer with knowledge of maintainability assessment and reliability-centered maintenance (RCM) and a system engineer with the knowledge of system dependability.

However, such a structure is difficult to implement in a Russia company: the design engineer is busy developing models and releasing drawings, the service engineer does repairs and is involved with warranty-related financial matters, and to find a system engineer is difficult as well. Additionally, it must be taken into consideration that collection and analysis of data must be done continuously, which requires the development and administration of databases.

In [9], the matters related to the role of the dependability unit of a company are raised as well. The unit's close association with the quality service is noted. However, in the presented diagram [9, p. 45] the dependability unit is independent and is subordinated to the Warranty Director. It should be noted that the structure does not show lines of interaction between the dependability unit, the design bureau and the quality service.

Thus, the following organizational structure of the dependability bureau is proposed (Fig. 1). This structure implies the independence of the dependability unit from

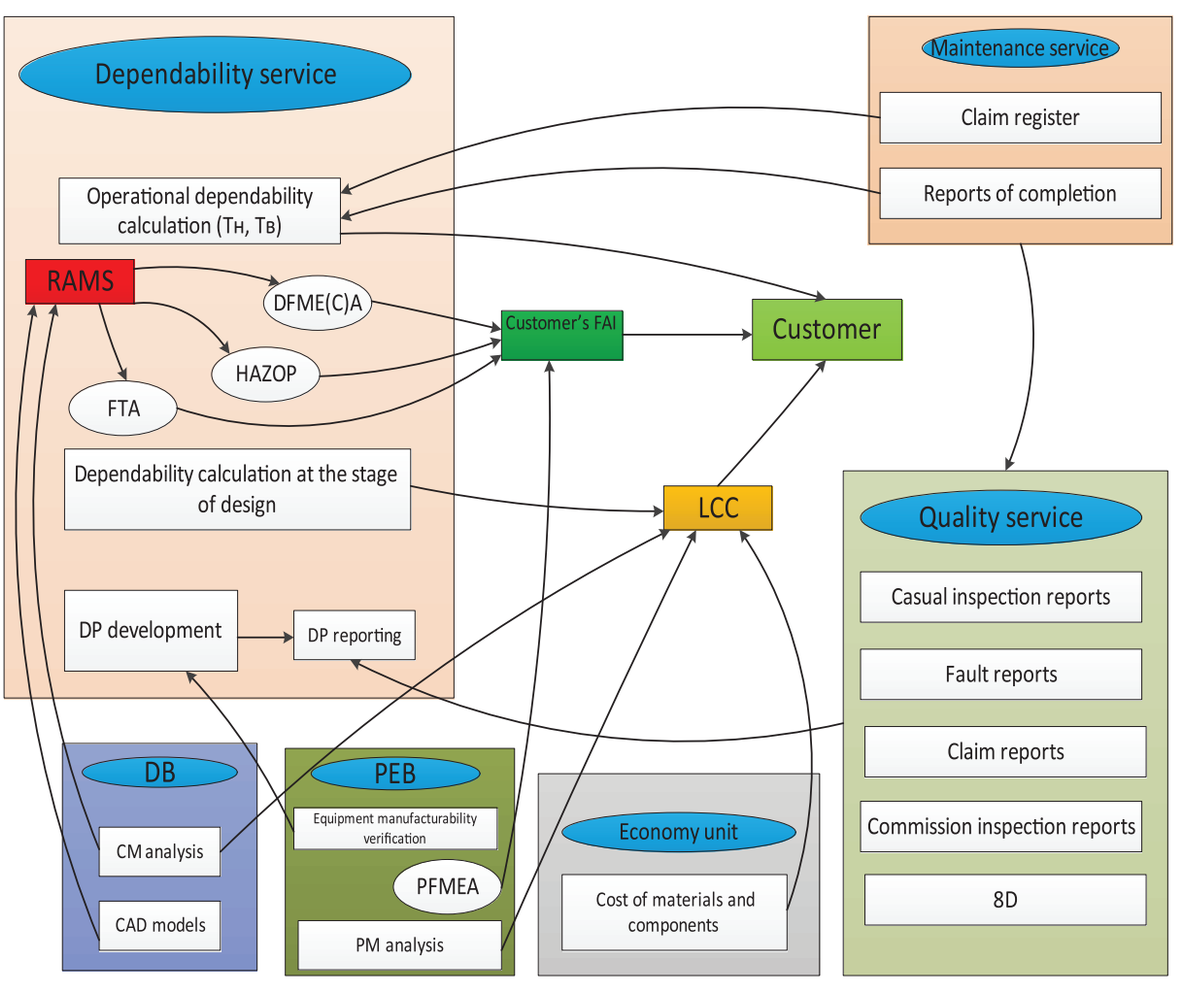


Figure 3 – Interactions between the dependability service and other business units of a company.

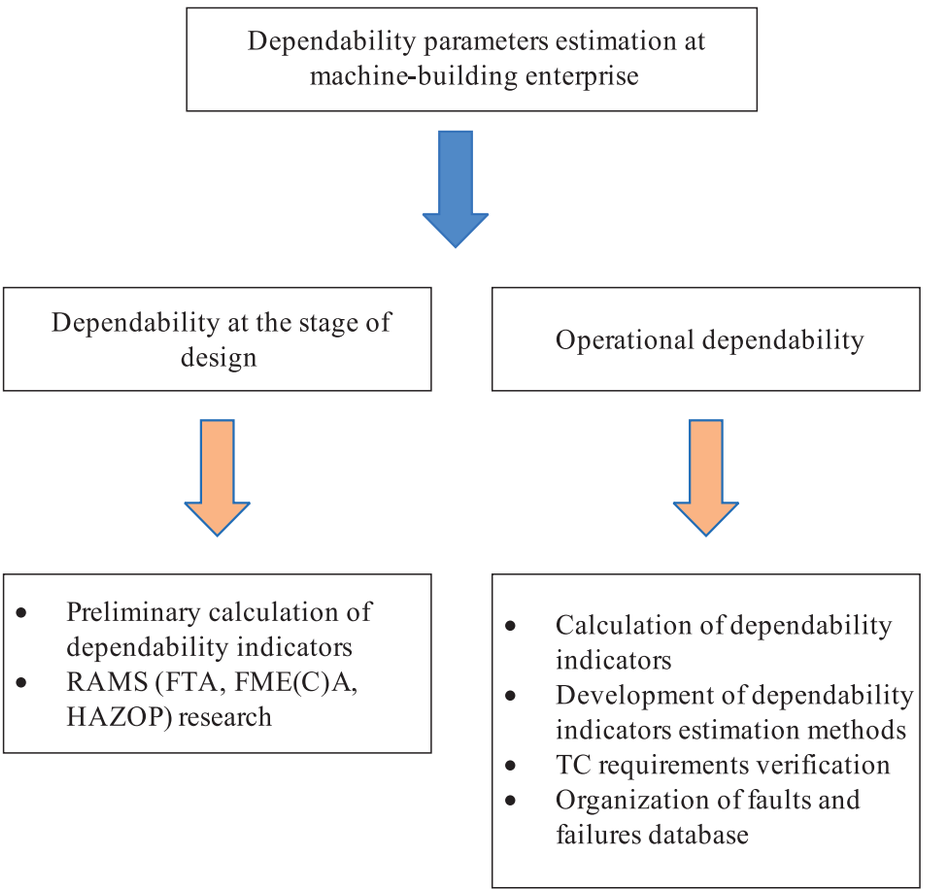


Figure 4 – Estimation of dependability parameters in a machine-building company.

the key technical units of the company and direct subordination to its Technical Director. The dependability service is involved with a wide range of matters, therefore at least two engineers are required, which would enable multitasking. A situation when one of the engineers has a degree in general engineering and another is a mathematician is optimal. Aside from engineers, the operation of the dependability service must also involve an IT specialist tasked with developing programs and applications for automated dependability calculation, as well as support of updating of databases.

Another important aspect is the relations between the maintenance service and the dependability unit. It is very important to clearly define the process owners at each level of failure information processing, otherwise the analysis of the causes of failures parameter evaluation may be complicated or undoable. The key element is the specialists who are responsible for the input of information per in and out of warranty repair reports, perform detailed analysis and evaluate every claim. The following model of interaction between the maintenance service and the dependability service is proposed (Fig. 2). In this structure the maintenance service is responsible for the following processes: claim register keeping, filling in completion reports and delivery of data to the dependability service, control of STPA stock status based on estimated data.

The dependability data collection system is to efficiently affect all the company's business processes and improve the dependability of the released products. This system is to provide the developer with comprehensive and clear data on past failures of units and elements, display the causes and measures taken to eliminate the failures [1].

The process of collection and processing of initial information on faults is to be automated to the fullest possible extent. This process is examined in detail in [10] using the example of the claim register form with a multilevel structure of the output product catalog of a transport machine-building company.

The interaction between the dependability service and a company's units is shown in Fig. 3. At the center of the diagram is the LCC block. Thus, we stress that the life cycle cost calculation is a company's primary goal that is addressed by the above units together, but the owner of the process is the Director General.

Formalization of the types of dependability service activities

The dependability bureau plays a crucial role in many of a company's processes, and subsequently releases a large amount of documentation: Fault Tree Analysis

(FTA), FME(C)A and HAZOP (Hazard and Operability) protocols, dependability indicator calculations, programs and methods of operational dependability testing. Dependability calculation can be subdivided into design and operational (Figure 4). Either one has its own specificity, yet they must be interrelated: the dependability indicators defined based on the information on similar products or calculated using specialized software at the stage of design must be verified at the stage of operation and fed back to design calculation. Feedback enables targeted identification of weak design elements, analysis of the causes of failures and timely design and engineering measures aimed at preventing the causes of recurrent failures [11].

Both the calculations and dependability analysis are to be formally documented at the stage of design and operational dependability calculations.

As of today, there are neither sound methods of such research, nor strict rules of documentation preparation. If dependability calculation at the stage of design can be represented as an RR (calculations) design document according to GOST 2.102-68, the fault tree analysis (FTA) does not have a common form of presentation and follows the recommendations of some translated foreign standards.

Matters related to human resources

Given the above, among the existing problems one should mention the lack of qualified personnel in the dependability estimation department. In the Federal State Educational Standard for Higher education there is no degree or program associated with technical system dependability, while in the Unified Skills Guide for Positions of Managers, Specialists and Non-manual Workers there is no such a position as “dependability engineer” (except from the aerospace industry). For that reason it is proposed to develop a corresponding Master’s program. The applicants must have a Bachelor’s degree in engineering or mathematics. The Master students must be offered an extended course of mathematical subjects, complex system dependability, as well as disciplines in the area of technical diagnostics.

Conclusion

The paper presents an organizational structure of the dependability unit of a transport machine-building company and examines the interactions between the dependability service and other units of a company.

This approach was proposed by the authors based on their own experience of operations in the dependability service of a company that produces rolling stock components, and the experience of interaction with the dependability units of customer companies.

An undeniable advantage of dependability engineering consists in the potential development of new methods in the process of dependability estimation of released products, implementation of plans for optimization of calculations and failure data classification. However, this potential may be thwarted due to the above factors, i.e.:

- absence of significant authority and competences in decision-making;
- poorly established interaction between the dependability unit and other business units (Fig. 3), which makes it impossible to coordinate dependability improvement measures;
- insufficiency of the interdisciplinary approach to the company-wide process organization in terms of dependability. In other words, a dependability engineer is assigned the role of primarily a design engineer, maintenance service engineer, IT specialist, etc., rather than functions associated with the calculation and analysis of technical system dependability.

The outlined approach to the organization of the dependability service is to clarify the role of dependability at all lifecycle stages to the top and project managers of machine-building companies. It must be understood that mistakes at early stages of dependability unit establishment, misunderstanding of the purpose and interaction between business units may cause financial losses. On the other hand, correct understanding of the functionality of the dependability service enables an efficient use of a company’s resources.

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The authors' contribution

Belousova M.V. Developed the structure of the dependability service, analyzed the process of interaction between the dependability service and the maintenance service and examined the personnel-related matters; reviewed the Russian experience of organization of dependability services in companies, summed up the primary dependability functions in a company and potential for future development.

Bulatov V.V. Analyzed the state of the art of the problem under consideration, reviewed the foreign experience of organization of dependability services in companies, proposed an organizational structure of the dependability service, described the interaction between the dependability service and other business units of a company.